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Rule-based Quantification and Mapping of Ecosystem Services Across Three Spatial Scales by Example of Germany

Schlutow A.[1], Schröder W.[2]*, Nickel S.[3], Jenssen M.[4]

[1] Öko-Data Ökosystemanalyse und Ökosystemdatenmanagement, Lessingstraße 16, 16356 Ahrensfelde, Germany, Angela.Schlutow@oekodata.de

[2]Chair of Landscape Ecology, University of Vechta, P.O.B. 1553, 49364 Vechta, Germany; winfried.schroeder@uni-vechta.de

[3]Planwerk Nidda, Unterdorfstraße 3, 63667 Nidda, Germany

[4] Evangelische Johanniter-Schulen Wriezen, Freienwalder Str. 1, 16269 Wriezen, Germany, jenssen@ev-johannitergymnasium-wriezen.de

*Corresponding author:

E-mail: Winfried.Schroeder@uni-vechta.de

Abstract *The state of ecosystems influences their services for humans. Therefore, the European Union aims to assess and map ecosystem conditions and ecosystem services at the level of the Union and the Member States, in order to implement maintenance or protection measures, if necessary. This paper aims at creating a methodology allowing to quantify and map the potential supply of selected forest ecosystem services over time, considering the influence of climate change and atmospheric nitrogen deposition which is, in contrast to previous approaches, reproducible. Therefore, the methodology was operationalised in a rule-based manner enabling to quantify and map ecosystem services at the local, regional and national level using Germany as an example. To this end, in a first step 125 near natural forest ecosystem types covering Germany were grouped into 78 classes according to the degree of similarity of their ecological characteristics that influence the provision of ecosystem services. Thereby, ecoclimatic, soil, hydrological, nutrient balance characteristics and 12 potential ecosystem service capacities were taken into account. Three potential ecosystem services (habitat, carbon storage, primary production) were quantified for selected representatives of the ecosystem type classes according to complex, but fully transparent rules, and mapped at the local, regional and national level.*

Keywords: Ecosystem condition; ecosystem integrity; EU Biodiversity Strategy; Geographic Information System.

1. Introduction

Ecosystem services are the benefits that people receive from ecosystems. They depend on ecosystem structures (e.g., biotic and abiotic ecosystem elements) and on their energetic and material relationships, i.e., their functions, and on the biological, chemical and physical processes (processes) underlying them. If ecosystem structures and functions move away from a defined reference state, stages of change in ecosystem integrity up to the replacement of one ecosystem type by another can be illustrated using quantitative data from environmental monitoring and modelling. Ecosystem integrity determines the provision of ecosystem services such as regulating services (e.g., nutrient, climate regulation, erosion control), supply services (e.g., food, water, fuels) and cultural services (e.g., recreation, landscape aesthetics).

According to Objective 2 Measure 5 of the European Biodiversity Strategy, all EU Member States are required to "map and assess the state of ecosystems and their services in their national territory" ([1], p. 5). Sohel et al. [2] emphasised the methodologically necessary consideration of quantitative biophysical indicators and empirical modelling. Therefore, the aim of this research is to develop and present a methodology with which ecosystem services can be classified and mapped in a rule-based, transparent and automated way on the basis of monitoring data and data modelled for projections for Germany as a whole, for regions (e.g., Kellerwald National Park, German federal state Hesse) and individual forest locations [3].

2. Methods

A few central building blocks from the extensive methodology are presented here. One essential component is the classification of Germany's forest ecosystems into 125 types, based on soil and vegetation data, for approximate 22,000 forest stands. These forest types were mapped throughout Germany. The respective information representing the condition of forest ecosystems before and during the World Meteorological Organisation´s reference period 1961-1990 was linked to further information enabling the quantification of ecosystem services: ecoclimatic zones according to plant- geographical distribution patterns, soil moisture levels according to plant-physiological aspects, nutrient cycle types based on the C/N ratio in the topsoil and base saturation over the entire rooting zone. Based on this, the 125 ecosystem types were aggregated to 78 ecosystem type classes for which then the ecosystem service potentials

were quantified. This was based on their classification in numerous tables into the following six levels: 0 = no significant potential, 1 = very low potential, 2 = low potential, 3 = medium potential, 4 = high potential, 5 = very high potential. Thereby, the basic function is rule-based classification. Rule-based classifiers are just another type of classifier, which makes the class decision depending on various "if … else" rules. Out of fourteen ecosystem services quantified, the following three of them were exemplarily mapped for the whole territory of Germany, for North Hesse and adjacent low mountain range and for the ICP Forests site Level II-608 / National Park Kellersee: The *Habitat Service* potential of current near- natural ecosystem types, the *Carbon Storage Service* potential and the *Primary Production Service*.

The rule-based quantification ecosystem services potentials of current near-natural ecosystem types relied on the following equations. Each of the factors in the equations was quantified by a bunch of rules defined in tables not included here:

L = N+((R-N)*0.5)+((H-N)*0.25)+((S-N)*0.125)+((W-N)*0.06)+((M-N)*0.03)+((B-N)*0.015) with: L = Score for *habitat function*, N = Hemeroby (= a measure for closeness to nature), R = classification points for the relative compositional completeness of flora and characteristic vegetation structure, H = Score for habitat value for fauna, S = Score for the need for protection, W = Score for recoverability, M = Score for the structural Maturity, B = Score for the position in the biotope network system.

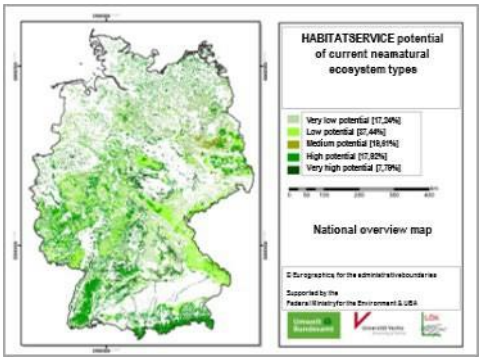
K = T+((S-T)*0.5)+((D-T)*0.25) with: K = Score for *carbon storage function*, T = Score for clay content, S = Score for spreading mass production, D = Score for destructor activity.

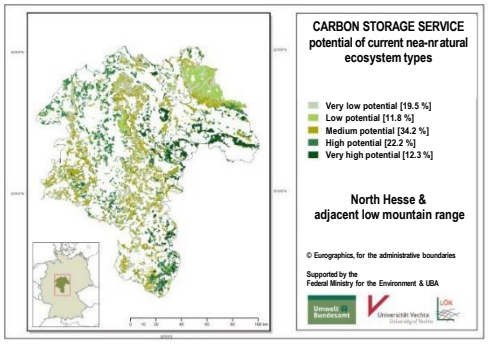
NPP = P+((W-P)*0.5)+((N-P)*0.25)+((G-P)*0.125)+((K-P)*0.06) with NPP = Score for total biomass *primary productivity*, P = Score for net plant physiological primary production (annual above-ground timber growth), W = Score soil water balance, N = Score for nutrient balance, G = Score for the soil structure, K = Score for climate.

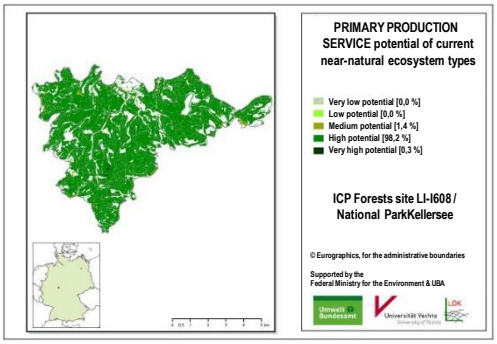
The respective results were tabulated and mapped accordingly.

3. Results

The results of the quantification were mapped for each ecosystem service on three spatial levels, exemplarily shown in the following maps. As mentioned in Section 2, these ecosystem service potentials refer to the reference state of the ecosystem types, which is based on data collected before (partly from 1920 onwards) and in the WMO reference period 1961-1990. Deviations from this can be measured for data collected after 1991 and for possible future developments up to 2070 based on modelling, and could justify appropriate adaptation measures.







References

[1] EU (European Union) (2011) The EU biodiversity straegy to 2020. Publications Office of the European Union, Luxembourg. https:// doi. org/ 10. 2779/ 39229. ISBN 978-92-79-20762-4.

[2] Sohel MSI, Ahmed Mukul S, Burkhard B (2015) Landscape's capacities to supply ecosystem services in Bangladesh. A mapping assessment for Lawachara National Park. Ecosyst Serv 12:128–135.

[3] Schlutow A, Schröder W 2021. Rule-based classification and mapping of ecosystem services with data on the integrity of forest ecosystems. Environ Sci Eur 33(50):1-34.

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